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Analysis of fuel and energy transition in Lithuanian households sector and its sustainable development in compliance with the EU policy

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ABSTRACT

The article provides the analysis of fuel and energy transition in Lithuanian households sector and its sustainable development after the integration of Lithuania into the European Union (EU) and covers the period 2005–2012.

Lithuania has limited quantity of indigenous energy resources and is depended from the import of energy resources, such as natural gas, petroleum and hard coal. Up to the year 2009 about 70–80% of electricity was produced from Ignalina NPP. At the end of 2009, according to the requirements of EU, Ignalina NPP was closed. Lithuania's energy dependence on the imports of fuel increased remarkably from 50.3% in 2009 to about 82% in 2010–2012 and considerably exceeded the EU average 54%. The share of renewable and indigenous energy sources in gross inland fuel and energy consumption increased from 14.7% in 2009 to 19.5% in 2012. About 40.4% of RES and indigenous energy belonged to households sector and 44.9% were transformed in Combined Heat and Power (CHP), and only 14.7% belonged to industry and other sectors.

In article, the sustainable development of Lithuanian and European households were overviewed and recent analysis of Lithuanian households sector was carried out. Dwellings were sorted by the year of construction. Distribution of households by dwelling type and heated area was assessed. Final fuel and energy consumption and distribution by different consumer groups were shown. In 2009–2012 final fuel and energy consumption of Lithuanian households comprised about 65 PJ or 33% of all final consumption. Household's energy consumption by different energy sources was disclosed. In 2012 about 36.5% of household's energy consumption belonged to solid biofuels and about 31.7% to heat energy. Electricity consumptions of households and electricity prices for household consumers were indicated and comparisons with EU-27 countries were made. Lithuanian RES flows diagram was constructed and RES share for households was revealed. The reduction of greenhouse gases emissions in Lithuania and other European countries was indicated.

Contents

Abbreviations: CHP, Combined Heat and Power; EC, European Commission; EPBD, Energy Performance of Buildings Directive; ESCo, Energy Services Companies; EU, European Union; GDP, Gross Domestic Product; GHG, Greenhouse Gases; IEA, International Energy Agency; ktoe, Kilotons of oil equivalents; LEI, Lithuanian Energy Institute; LTL, Lithuanian Litas (1 LTL=0.2896 €); NPP, Nuclear Power Plant; OECD, Organization of Economic Cooperation and Development; PV, Photovoltaic; RES, Renewable Energy Sources; UK, United Kingdom; USA, United States of America; ZEB, Zero Energy Buildings

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1. Introduction

1.1. Sustainable development of the European households

Sustainable development is a fundamental and overarching objective of the European Union, enshrined in the Treaty. The EU sustainable development strategy, launched by the European Council in Gothenburg in 2001 and renewed in June 2006, aims for the continuous improvement of quality of life for current and future generations [1].

Household expenditure in EU rose steadily between 2000 and 2007, but dropped slightly in 2008 and 2009, as a consequence of the economic crisis. In parallel, the number of people per household decreased, reflecting a continuous trend towards more but smaller households. Electricity consumption of households rose substantially in 2000–2009, but final energy consumption decreased slightly mostly as a consequence of the economic crisis. Household consumption (the ultimate end to which production activities are directed) is characterized through the number, size and composition of households and their expenditure patterns. These characteristics influence all indicators in the ‘consumption patterns’, especially electricity consumption.

Sustainable consumption and production patterns are key elements in tackling climate change. Reduction in energy consumption and changes in the fuel mix, by switching to less carbon-intensive energy sources, is linked to lower CO_2 emissions. Transition to a low carbon economy would be an important step towards meeting this demand for climate stability. The coming sustainable energy transition in the world, past and prospective its history, strategies and outlook were outlined in [2,3].

Buildings occupy a key place in our lives and society as a whole. Yet, the energy performance of our buildings is generally so poor that the levels of energy consumed in buildings place the sector among the most significant CO_2 emissions sources in Europe. While new buildings can be constructed with high performance levels, it is the older buildings, representing the vast majority of the building stock, which are predominantly of low energy performance and subsequently in need of renovation work. With their potential to deliver high energy and CO_2 savings as well as many societal benefits, energy efficient buildings can have a pivotal role in a sustainable future [4]. Sustainability at home, policy measures for energy-efficient appliances was studied in [5].

Achieving the energy savings in buildings is a complex process. Policy making in this field requires a meaningful understanding of several characteristics of the building stock. Reducing the energy demand requires the deployment of effective policies which in turn makes it necessary to understand what affects people's decision making processes, the key characteristics of the building stock, the impact of current policies, etc.

It was estimated [4] that there are 25 billion m^2 of useful floor space in the EU-27, Switzerland and Norway. Half of the total estimated floor space is located in the North and West region of Europe while the remaining 36% and 14% are contained in the South and Central and East regions, respectively.

Residential buildings comprise the biggest share (about 75%) of the EU's building stock and are responsible for the majority of the sector's energy consumption. A substantial amount of the stock in Europe is older than 50 years. More than 40% of residential buildings have been constructed before the 1960s, when energy building regulations were very limited.

The performance of buildings depends on a number of factors, such as the performance of the installed heating system and building envelope, climate conditions, behavior characteristics and social conditions. Data on typical heating consumption levels of the existing stock by age shows that the largest energy saving potential is associated with the older building stock, were in some cases buildings from 1960s are worse than buildings from earlier decades. In 2009–2011, European households were responsible for about 68% of the total final energy use in buildings. Energy in households was mainly consumed by heating, cooling, hot water, cooking and appliances, where the dominant energy end-use in homes (about 70%) was space heating. Buildings are at the pivotal center of our lives. The characteristics of a building, its design, look and feel, and technical standards not only influence our productivity, our well-being, moods and our interactions with others, they also define how much energy is consumed in, and how much heating, ventilation and cooling energy is needed to create a pleasant environment [4].

Buildings cause a significant amount of greenhouse gas emissions, mainly CO_2, altering our planet's climate. By renovating buildings to high standards of efficiency we can demonstrate that ambitious climate change mitigation actions and improvements in living quality can go hand in hand. The European building stock with its unique mix of historical and modern architecture provides both significant opportunities and challenges. Effective policies and incentive schemes to reduce the climate change footprint of buildings require a solid understanding on the current building stock.

Energy use in residential and commercial buildings represents the lion's share, about 40% of the EU's total final energy consumption and CO_2 emissions. Activities related to buildings represent a large part of the EU economy, about 9% of EU GDP [6]. Therefore, the EU buildings sector can play a key role in achieving EU growth, energy and climate policy objectives, while contributing to improved level of comfort and lower energy bills for citizens. Energy efficiency of buildings is an important part of broader initiatives on achieving EU energy and climate change objectives. The potential for cost-effective energy savings is about 30% of the whole sector's expected energy consumption by 2020, which would lead to significant economic, social and environmental benefits. The existing EU core instruments in this context, e.g. Energy Performance of Buildings Directive (EPBD), Eco-design of Energy-using Products Directive, and Energy End-use Efficiency and Energy Services Directive, have proved to be a solid basis for

achieving and supporting energy savings in the buildings sector. Amongst them, the EPBD is the main tool that provides a holistic approach towards efficient energy use in the buildings sector.

The main objective of the EPBD is to promote cost-effective improvement of the overall energy performance of buildings, whilst taking into account local conditions and requirements. The Directive covers the energy needs for space and water heating, cooling, ventilation and lighting. It provides a holistic view on the energy use of buildings and combines in a legal text different regulatory (i.e. minimum energy performance requirements) and information based instruments (i.e. certificates and inspection requirements):

- Member States have to set up minimum energy performance requirements for new buildings and for large existing ones that undergo major renovation. This means that these buildings shall meet certain national and regionally determined minimum energy performance levels, with the aim of achieving improved energy performance, thermal comfort and lower energy bills.
- Member States have to introduce an energy performance certification scheme that provides information on the energy needs of a building and on what can be improved. It should be presented to potential buyers/tenants so that they have an independent assessment of the energy-use aspects of the buildings, enabling informed decisions to be taken.
- Member States shall establish a system for inspection of medium- and large-size heating and air-conditioning systems at regular intervals so that their energy performance can be monitored and optimized.

These three main instruments take effect at different times of a building's lifetime.

Minimum energy performance requirements are to be met at the time of construction or major renovation (i.e. every 25–40 years approx.). An energy performance certificate is required only when buildings are newly constructed, sold or rented out and is valid for a maximum of 10 years.

Member States also have to develop their own methodology, or use European standards, for calculating the energy characteristics and performance of buildings, whilst also ensuring that there are enough qualified experts to carry out the certifications and inspections.

The EPBD does not fix concrete EU-wide energy performance requirements, but obliges Member States to lay down holistic methodologies, requirements, and inspection and certification regimes to rate the energy performance of buildings at a national/regional level. Thus, its approach takes national/regional boundary conditions, like outdoor climate and individual building traditions, fully into consideration and respects the subsidiary and proportionality principles. Member States can go beyond the minimum prescriptions laid down in the Directive and be more ambitious.

Some 36 million European households are in high-rise residences and yet many of the buildings are in urgent need of refurbishment. Refurbishment requires collective agreement on a capital investment, which is difficult to establish especially when some occupants expect to live in the building over longer-term but others only for the short-term. Furthermore, in most cases the occupants of high-rise residences are not among the wealthier members of society and they find it difficult to raise capital for longer-term investments. It is not surprising, then, to find that this section of the building stock is the most neglected and that there remain significant cost-effective opportunities for it to be refurbished in a way that improves comfort, saves energy, reduces CO_2 emissions and significantly improves the urban environment.

Buildings are the largest energy-consuming sector, accounting for over one-third of final energy consumption globally and an equally important source of carbon dioxide (CO_2) emissions. In certain regions highly dependent on traditional biomass, energy use in buildings represents as much as 80% of total final energy use [7].

The buildings sector, including the residential and services subsectors, uses a wide array of technologies. They are used in the building envelope and its insulation, in space heating and cooling systems, in water heating, in lighting, in appliances and consumer products, and in business equipment. The long lifetime of buildings and related equipment presents both challenges and opportunities for the sector. Some of the technologies needed to transform the buildings sector are already commercially available and cost effective, with payback periods of less than five years. Others are more costly and will require government intervention if they are to achieve wide market uptake.

The transformation of the buildings sector will have positive benefits for other sectors, most notably for the power sector, as more than half of all electricity consumed today is used in buildings. Electricity savings in buildings will have far-reaching benefits for the power sector and will translate into avoided electrical capacity additions, as well as reduced distribution and transmission network expansion, with potentially huge savings for utilities.

Examples of best available building technologies combined with renewable energy sources in advanced buildings, such as zero-energy buildings, only represent a small niche market today. With the world economy struggling, policy makers need to realize that promoting building energy efficiency can increase jobs, support economic development and lead to reduced energy consumption.

If no action is taken to improve energy efficiency in the buildings sector, energy demand is expected to rise by 50% by 2050. This increase is driven by rapid growth in the number of households, residential and services floor area, higher ownership rates for existing electricity-consuming devices and increasing demand for new products.

Energy trends in the buildings sector can vary significantly from country to country depending on a number of factors ranging from climate, population, income, economic development and household sizes.

The building envelope determines the amount of energy needed to heat and cool a building, and hence needs to be optimized to keep heating and cooling loads to a minimum. A high-performance building envelope in a cold climate requires just 20% to 30% of the energy required to heat the current average building in the Organization of Economic Co-operation and Development (OECD). In hot climates, the energy savings potential from reduced energy needs for cooling are estimated at between 10% and 40%.

1.2. Recent publications and studies on EU household sector

In recent years the concept of sustainable consumption has received increased attention. Household consumption in industrialized countries has been identified as a key contributing factor to global problems addressed in the sustainable development debate such as climate change, depletion of energy resources and biodiversity loss.

Towards more sustainable household consumption patterns indicators to measure progress and environmentally sustainable household consumption were discussed in [8,9]. Sustainability assessment methods and techniques, criteria for sustainability assessment of state policies were analyzed by Lithuanian specialists [10]. Households as role models for sustainable consumption

(interplay between households as consumers and local governments as policy makers and service providers) were researched in [11]. Developing policies and instruments for sustainable household consumption (experiences and role of governance in the design of policy instruments for sustainable consumption) were analyzed recently by Irish experts [12]. A good job on study energy efficiency and intensity in the North American households was done in IEA information paper [13]. A review on the basics of building energy estimation was performed by USA expert in [14]. The structure of the European housing stock, composition by type, useful floor area, energy consumption and efficiency, sustainable energy management, were disclosed in [15]. The energy-efficient upgrades of multi-story residences in the EU and how much information disclosure of building energy performance is necessary were analyzed in [16,17]. User innovations in sustainable home energy technologies (home heating systems) were disclosed in [18]. Energy consumption and economic analyses of a district heating network, modeling of micro-CHP (Combined Heat and Power) unit and penetrating of CHP into domestic energy supply structure were studied in many works [19–23]. Flexibility of CHP system with thermal energy storage for district heating system was investigated in [24]. Climate and energy country profiles (key facts and figures for EEA member countries) and European framework for energy and climate policies were overviewed in [25,26]. The effect of improved efficiency on energy savings in EU-27 buildings and technical potential for energy saving measures in the residential building stock (technical effects of 12 energy saving measures) were assessed in [27,28]. Energy efficiency initiatives in the building stock, the impact factors on heating demand and the reliability of technological systems with high energy efficiency in residential buildings were analyzed in [29–31]. Energy and economic analysis for large-scale integration of photovoltaic (PV) systems in buildings (technical, economic and cost analysis), impact of residential PV adoption on retail electricity rates and how PV will change electricity markets in Europe fundamentally (the possible effects on the prices in electricity markets) were investigated in [32–34]. Financial analysis on the proposed renewable heat incentive for residential houses (study on the solar thermal system) in the UK was made in [35]. Thermo-economic assessment of end user value in home and community scale renewable energy systems was made in [36]. Innovative method of RES integration into the regional energy development scenarios and numerical study on hybrid heat pump systems in existing buildings were studied in [37,38]. Sustainable renovation of residential buildings and the influence of energy audits on the energy efficiency investments of private owner-occupied households were researched in [39,40]. Social barriers to the adoption of smart homes and smart home technologies through the analysis of expert views and method for a component-based economic optimization in design of whole building renovation were overviewed in [41,42]. The application of Energy Services Companies (ESCo) as a business model for heat entrepreneurship was discussed in [43]. In recent years there is a growing interest in the zero energy buildings (ZEBs) [44–46]. Towards nearly zero-energy buildings, the state-of-art of national regulations in Europe were reviewed in [47]. Improving the renewable energy mix in a building toward the nearly zero energy status and energy performance of net-zero and near net-zero energy homes were investigated in [48,49]. Assessment of technical and economical viability for large-scale conversion of single family residential buildings into zero energy buildings and advanced control of heat pumps for improved flexibility of net-zero energy building (Net-ZEB) towards the grid were analyzed in [50,51]. Scenarios, business models and examples for very low-energy housing markets were researched by specialists of VTT Technical Research Centre of Finland [52]. Implementation of Energy Performance Building Directive (EPBD) 2010/31/EU in Lithuania, status at the end of 2012 was described in [53].

The status and perspectives of renewable energy policy and deployment in the European Union and what is required to reach the 2020 targets were analyzed in [54]. The analysis of the renewable energy directive by a techno-economic optimization model and analysis of the latest data on energy from renewable sources was made by experts in [55,56]. The analysis of the renewable energy use in the EU was investigated by many researchers [57–62]. Proposed measures on renewable heat, electricity and energy efficiency have achieved important results, however sometimes they lack sustainability, security of supply and competitiveness. The optimization criteria for energy systems analyses of renewable energy integration were reviewed in [63]. The policies to support the growth of RES of heat were overviewed in “Energy Policy” editorial paper [64]. How will renewable power generation be affected by climate change and the results of the impacts of climate change on the European energy system were assessed in [65,66]. Global warming mitigation and renewable energy policy development from the Kyoto Protocol to the Copenhagen Accord were commented in [67]. The impact of international GHG trading regimes on the penetration of new energy technologies and feasibility to implement EU Energy and Climate Package targets was reviewed in [68]. How to ensure GHG reductions and suitability of the EU sustainability criteria were analyzed in [69].

1.3. Overview of Lithuanian household studies

General overview of the Lithuanian power system and promoting interactions between local climate change mitigation and sustainable energy development in Lithuania were described in [70,71]. Sustainable energy development in Lithuania, tendencies of RES usage, promotional policy and implementation status of renewable energy technologies were analyzed in [72]. Governmental policy and prospect in electricity production from RES in Lithuania, uses of RES in district heating systems and dependence of heat energy supply on average outside air temperature were examined by LEI experts in [73–75]. Renewable energy in the Lithuanian heating sector, dynamics of district heating consumption and its share in household sector were analyzed by specialists in [76]. A comparative assessment of policies targeting energy use efficiency in Lithuania and its household sector was carried out in [77]. A multi-objective ranking of climate change mitigation policies and measures as well as the impact of household behavioral changes on GHG emission reduction in Lithuania was disclosed in [78,79]. The sustainable Lithuanian economy development and changes of fuel and energy consumption were studied by authors in [80,81]. The Lithuanian RES sector's strategy (vision, current situation, strategic initiatives) was disclosed in National Energy Independence Strategy of 2012 [82].

According to the data of Statistics Lithuania [83], in 2012, compared to 2011, gross inland fuel and energy consumption in Lithuania increased by 1.1% and amounted to 309.2 PJ (in 2011, 305.9 PJ). To satisfy the domestic consumer needs, domestic and imported fuels as well as energy resources were used. In 2012, compared to 2011, imports of the main fuel and energy resources decreased: coal – by 17.9%, natural gas – 2.6%, electricity – 1.7%.

Furthermore, after the closure of Lithuanian Ignalina NPP in 2009, Lithuania remains energetically dependent on imported organic fuel. Lithuanian energy dependence rate slightly decreased from 79% in 2011 to 77.9% in 2012 and considerably exceeded the EU average.

In 2012, the largest portion of gross inland fuel and energy consumption was made up of natural gas (35.9%) and petroleum products (34.2%). In order to reduce the country's dependence on

imported fuel and the impact of fossil fuel on the environment, a wide use of renewable energy resources is of great importance.

Today the greatest renewable energy potential in Lithuania is shown by solid biofuel. In 2012, the largest amount thereof (55.9%) was used in households and for the production of electricity and centralized heat supply (31%). The consumption of solid biofuel for the production of electricity and centralized heat supply increased by one-third: from 9.9 PJ in 2011 to 13.0 PJ in 2012. Biogas production in Lithuania amounted to 24.2 million m^3 in 2012.

Electricity production grew by 4.6% from 2011 to 2012 and amounted to 5042.4 GWh.

Wind farms operating in Lithuania also contributed to the increase in electricity production. In 2012, compared to 2011, electricity production on wind farms increased by 13.7% and accounted for 10.7% of the total electricity production in the country.

Another source of RES is solar energy. The amount of sunlight in Lithuania is not sufficient to widely develop this type of energy production. In 2012, the use of solar energy noticeably increased and energy supplied to electricity networks amounted to 2316 MWh (in 2011, 76 MWh).

The use of biofuel reduces the direct environmental pollution. Biodiesel and bioethanol are the most popular biofuels in Lithuania. In 2012, biodiesel consumption in the country amounted to 58.6 thousand tonnes, or 1.5 times more than in 2011, bioethanol consumption – 13.5 thousand tonnes, or by 8.2% less than in 2011.

In 2012, compared to 2011, final energy consumption increased by 2.6%. Among final consumers, transport and household sectors predominated, which consumed, respectively, 32.5 and 31.8% of energy in 2012. In the transport sector, the largest portion of consumption was made up of petroleum products, in the household sector – of renewable energy resources and centrally supplied heat.

Table 1
Lithuanian residential buildings by the type of houses and year of construction. [a]

Year of construction	Multi-family houses		Single and two-family houses	
	Units	Percent	Units	Percent
Before 1940	10,311	27.6	115,907	26.3
1941–1960	3750	10.0	86,599	19.7
1961–1990	20,118	53.8	193,777	44.1
1991 and beyond	3200	8.6	43,484	9.9
All dwellings	37,379	100	439,767	100

[a] Lithuanian statistics data 2012.

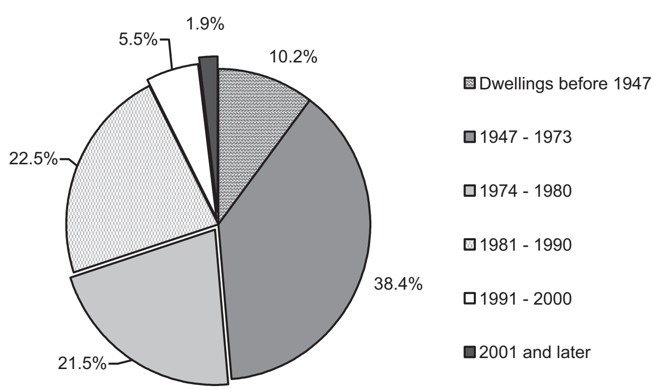

Fig. 1. Lithuanian dwellings by the year of construction.

2. Analysis of the Lithuanian household sector

Household refers to a person living alone or a group of persons sharing the same living accommodation and expenditure, including collective provision of vital needs. Energy consumption in households encompasses fuel and energy supplied to the population for heating, lighting, cooking.

According the Lithuanian statistics, in 2012 in Lithuania were 37,379 apartment blocks, 439,767 single and two-family houses and 1752 houses for various social groups; total – 478,898 residential buildings. Lithuanian residential buildings by the type of houses and the year of construction are shown in Table 1. Non-residential buildings in Lithuania were 206,128 (without the auxiliary farm buildings) from the total buildings amount 685,026.

According to the data from the Real Property Register of the State Enterprise Centre of Registers, as of 31 December 2012, the stock of dwellings amounted to 85.8 million m^2 of useful floor area [83]. 54.5 million m^2 of such amount were in urban and 31.3 million m^2 – in rural areas. Private property in urban and rural areas accounted for 98% of the total stock of dwellings.

The stock of dwellings in Lithuania in 2012 comprised of 1289.1 thousand dwellings, i.e. there were about 429 dwellings per 1000 population. Most of them were two- and three-room dwellings: in

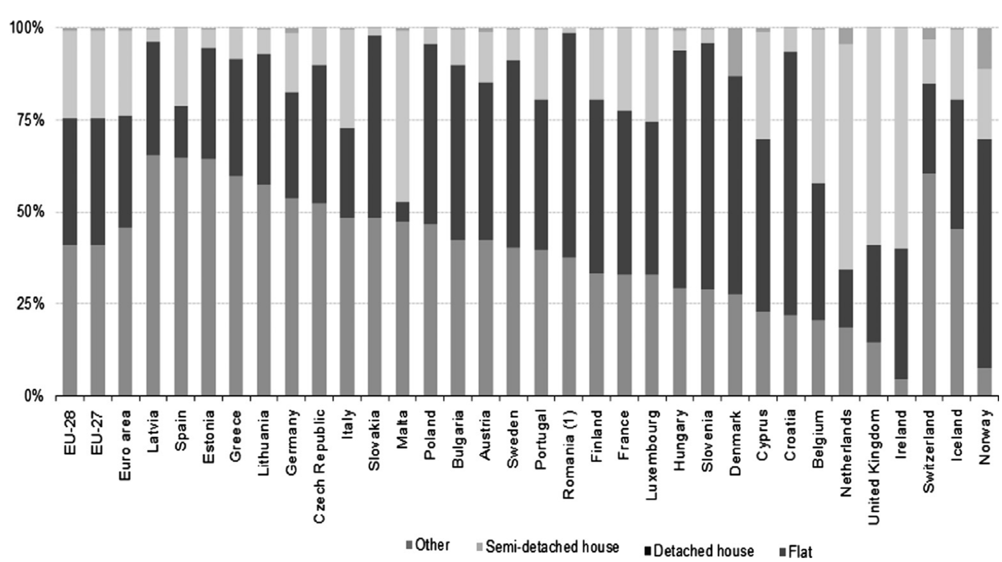

Fig. 2. Distribution of population by dwelling type in Lithuania and EU-27 countries in 2011.

urban areas – 38.9% and 25.5%, in rural areas – 26.0% and 32.3% respectively. The average size of a dwelling was 66.6 m², in urban areas – 60.8, in rural areas – 79.8 m^2.

Dwellings with one household comprised about 95% of all dwellings in Lithuania and with two or more households – only 5%. Moreover, households with 1–2 persons comprised 64.2%, 3–4 persons – 30.4%, 5 and more persons – 5.4%. About 69.4% of dwellings were in urban area and about 30.6% in rural area. Also, 96.6% of dwellings were owned and only 3.4% rented.

2.1. Dwellings by the year of construction

In Lithuania 10.2% of dwellings were built before 1947, 38.4% – in 1947–1973, 44% – in 1974–1990, 5.5% – in 1991–2000 and 1.9% – in 2001 and later.

All Lithuanian dwellings by the year of construction are shown in Fig. 1.

Number of dwellings per 1000 of population in Lithuania was around 429 in 2012 and average useful floor area per capita – 28.6 m^2 (about 27.2 m^2 in urban areas and 31.4 m^2 in rural areas). The useful floor area of dwellings stock in Lithuania was 85.8 million m^2 in 2012, from which 63.5% belonged to urban and 36.5% to rural areas.

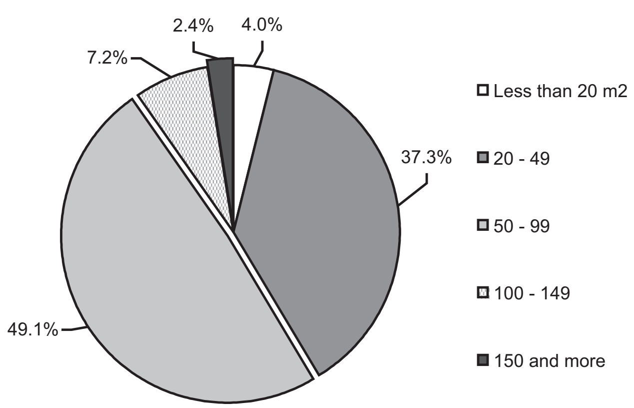

Fig. 3. Distribution of households in Lithuania by heated area, m^2.

2.2. Distribution of population by dwelling type

In 2011, the share of persons living in flats in Lithuania comprised about 57%, in detached house – about 35% and semi-detached – about 7%. The share of persons living in flats was the highest across the EU Member States in Latvia (65.3%), Spain (64.9%) and Estonia (64.5%), Fig. 2 [84].

The share of people living in detached houses peaked in Croatia (71.7%), Slovenia (66.8%), Hungary (64.7%), Romania (60.8%) and Denmark (59.2%); Norway also has a high share (62.3%) of its population living in detached houses. The highest percents to live in semi-detached houses were reported in the Netherlands (61.2%), in Ireland (59.9%) and in the United Kingdom (58.9%).

In 2011, 40.9% of the EU-27 population lived in flats, just over one third (34.7%) in detached houses and 23.6% in semi-detached houses.

2.3. Distribution of households by heated area

The average useful floor area per capita in Lithuania amounted to 28.6 m², in urban areas – 27.2, in rural areas – 31.4 m^2. Useful floor area per capita in Vilnius city amounted to 27.0 m², Kaunas city – 27.9, Klaipėda city – 26.2, Šiauliai city – 26.1, Panevėžys city – 26 m². The largest average useful floor area per capita was in Ignalina district (41.2 m^2), Palanga city (39.4 m^2), Molėtai (38.4 m^2) and Anykščiai (37.6 m^2) district municipalities.

Distribution of households by heated area in Lithuania is shown in Fig. 3 [85].

Households with heated area 20–49 m^2 and 50–99 m^2 comprised correspondingly 37.3% and 49.1% or jointly about 86.4% of all households' heated area. Households with heated area less than 20 m^2 comprised about 4% and with more than 150 m^2 – only 2.4% [85].

2.4. Number of people per households

The average number of persons living in private households in Lithuania was 2.3 in 2012. From 2005 to 2012 such indicator in Lithuania decreased about 1.3 times from 2.9 to 2.3 persons per household. Private households are either a one-person household or a multi-person household, i.e. a group of two or more persons who jointly occupy the whole or part of a housing unit and provide themselves with food and possibly other essentials for living.

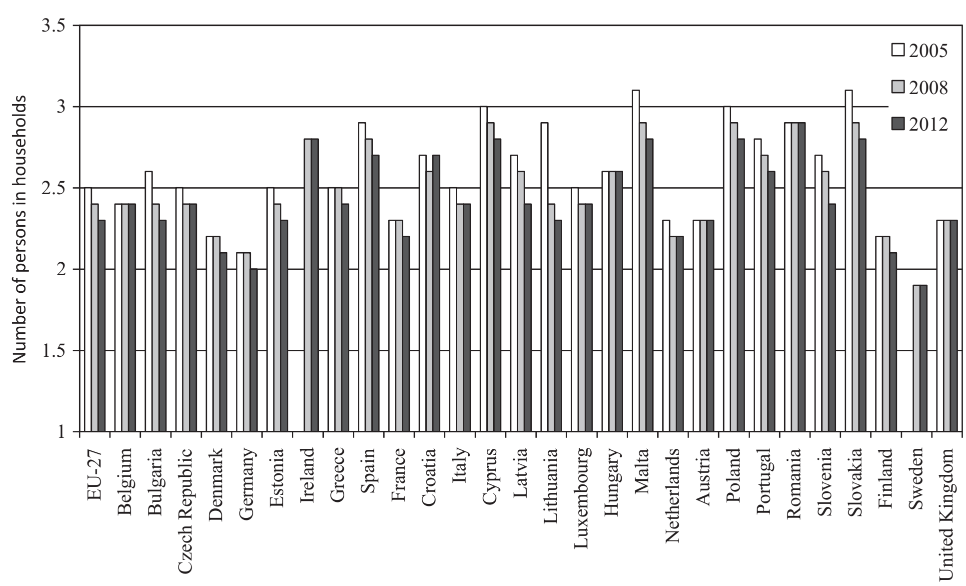

Fig. 4. Decreasing the number of persons per household in Lithuania and EU-27 countries for the period 2005–2012.

Decreasing the number of persons per household in Lithuania and EU-27 countries for the period 2005–2012 is shown in Fig. 4 [86].

The reduction of persons per household was observed in majority EU-27 countries. In Slovakia and Malta it decreased from 3.1 to 2.8, Poland and Cyprus – from 3.0 to 2.8, Slovenia and Latvia – from 2.7 to 2.4 persons per household.

On average, the number of persons per household in EU-27 countries decreased from 2.5 to 2.3 persons, reflecting the trend towards more but smaller households.

3. Gross inland fuel and energy consumption, share of the RES and its distribution

Lithuania has limited quantity of indigenous energy sources and was depended from the import of energy resources (natural gas, crude oil and hard coal).

The gross inland fuel and energy consumption in Lithuania for the period 2007–2012 varied in the range 295–392 PJ [87–89]. The peak of consumptions was in 2007–2008. In 2009, about 119 PJ of gross inland fuel and energy consumption belonged to nuclear, hydro, wind, geothermal and energy from chemical processes. About 104 PJ of gross inland fuel and energy consumption belonged to crude oil and petroleum products, 91 PJ – to natural gas, 39 PJ – to solid biofuels (firewood, wood and agricultural waste) and about 10 PJ – to coal, peat and other fuel.

At the end of 2009, according the requirements of EU, the Lithuanian Ignalina NPP was closed and the structure of gross inland fuel and energy consumption in Lithuania changed radically. In 2010 about 107 PJ of gross inland fuel and energy consumption belonged to crude oil and petroleum products, 104 PJ – to natural gas and about 39 PJ – to solid biofuels. Hydropower, wind, geothermal energy and energy from chemical processes consisted of about 33 PJ of gross inland fuel and energy consumption.

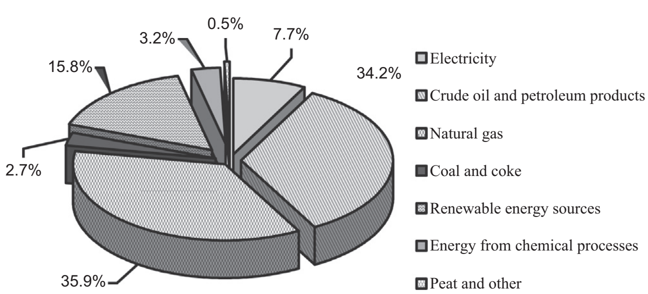

Fig. 5. Distribution of gross inland energy consumption in Lithuania by fuel and energy sources in 2012.

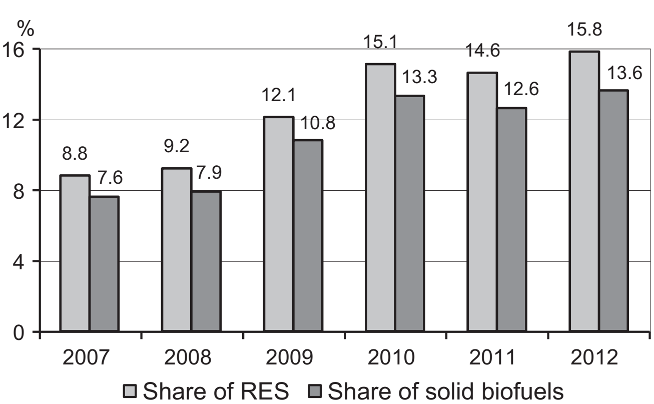

Fig. 6. Share of RES and solid biofuels in gross inland fuel and energy consumption in Lithuania in 2007–2012.

In 2012, 35.9% of gross inland fuel and energy consumption belonged to natural gas, 34.2% – to crude oil and petroleum products, 15.8% – to renewable energy sources, 7.7% – to electricity and 6.4% – to other fuel and energy (Fig. 5).

The share of RES in the gross inland fuel and energy consumption in Lithuania for the period 2007–2012 increased about 1.8 times from 8.8% to 15.8%, (Fig. 6).

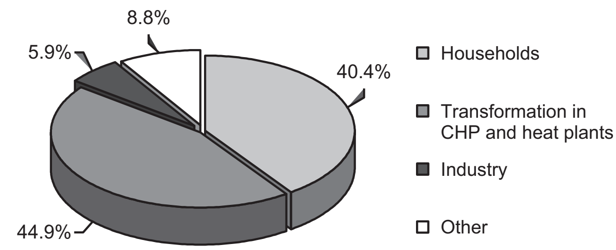

Fig. 7. Distribution of renewable and indigenous energy sources in Lithuania according to the economy sectors in 2012.

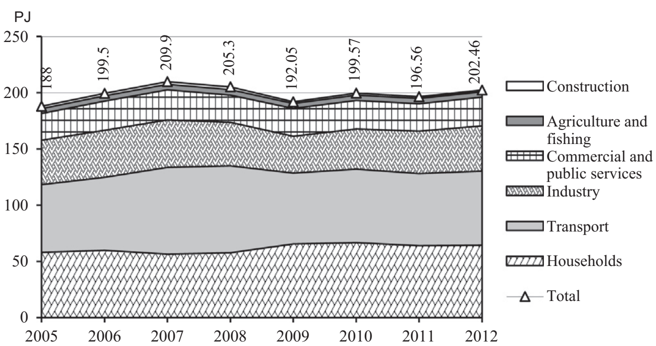

Fig. 8. Final fuel and energy consumption according to economy sectors in Lithuania.

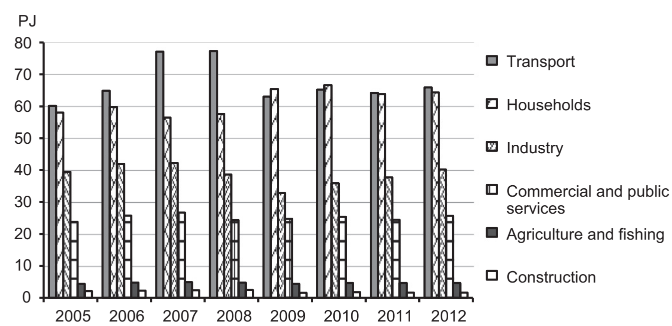

Fig. 9. Final fuel and energy consumption in Lithuania according to the user groups.

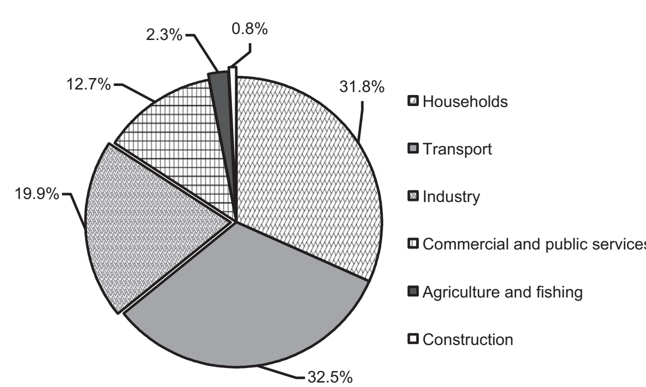

Fig. 10. Distribution of final fuel and energy consumption in Lithuania by the consumer groups in 2012.

The main compound of the RES was solid biofuels and consisted about 86–88% of the total RES consumption. Lithuanian household sector was one of the main RES and solid biofuels consumers for the period 2007–2012. The share of solid biofuels in gross inland consumption in Lithuania for such period increased also 1.8 times – from 7.6% to 13.6%.

Distribution of renewable and indigenous energy sources in Lithuania according the economy sectors in 2012 is shown in Fig. 7.

A huge share, about 40.4% of RES and indigenous energy sources in Lithuania belonged to households. About 44.9% – were transformed in Combined Heat and Power (CHP) and heat plants, 5.9% – in industry and 8.8% – in other sectors.

4. Final fuel and energy consumption in Lithuanian households in 2005–2012

Final fuel and energy consumption by economy sectors in Lithuania for the period 2005–2012 is shown in Fig. 8 [87–89].

From 2005 to 2007 the final fuel and energy consumption in Lithuania increased by 12% (from 188 to 210 PJ). In 2009 energy consumption decreased to 192 PJ (the consequences of the recession) and by 2012 slightly increased to 202 PJ.

4.1. Distribution of fuel and energy by the consumer groups

In 2005–2012 about 27–33% of final fuel and energy consumption (56–66 PJ) belonged to households sector. In 2009–2012 fuel and energy consumption in Lithuanian households changed marginally (approximately 3%) and was about 64–66 PJ. Also, about 33% (63–66 PJ) of final fuel and energy consumption belonged to transport sector, 17–20% (33–40 PJ) – to industry and about 13% (24–26 PJ) – to commercial and public services sectors (Fig. 9).

Distribution of final fuel and energy consumption in Lithuania according to the consumer groups in 2012 is shown in Fig. 10.

In 2012 31.8% of final fuel and energy consumption was consumed in Lithuanian households and it was comparable with transport energy consumption (32.5%).

Final fuel and energy consumption of residential sector in Lithuania and EU-27 countries in 2005–2009 and 2011 is shown in Fig. 11 [90].

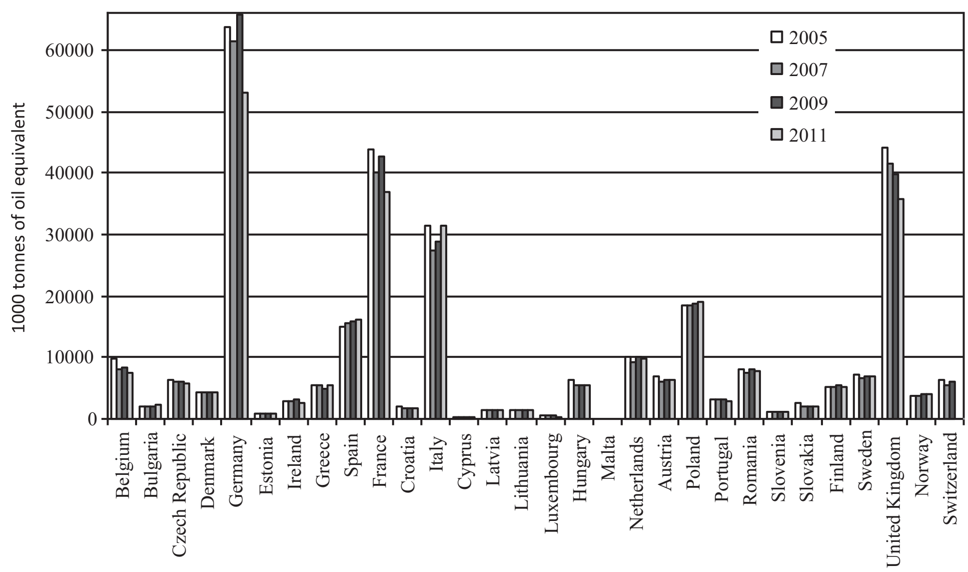

Fig. 11. Final fuel and energy consumption of residential sector in Lithuania and EU-27 countries in 2005–2009 and 2011.

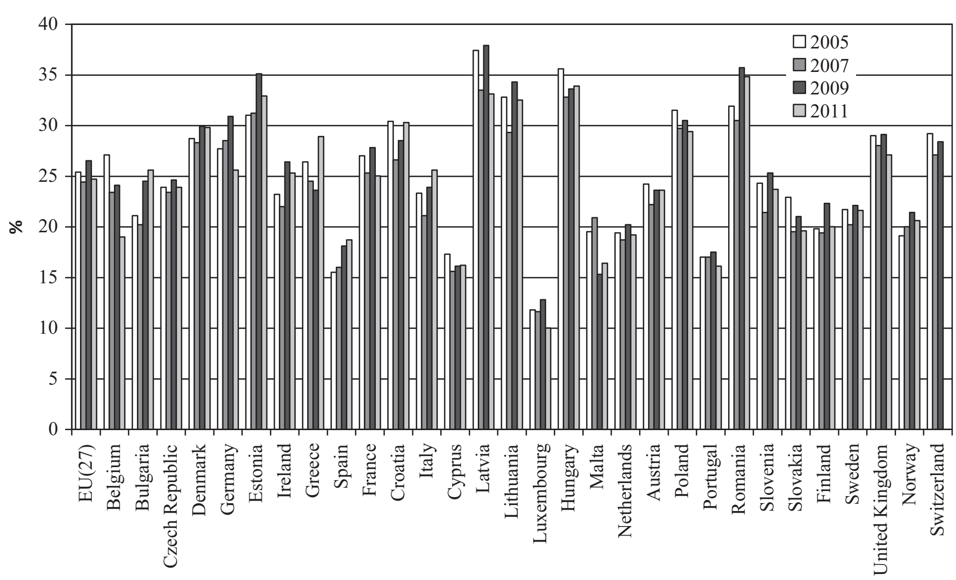

Fig. 12. Share of residential energy consumption in the total final energy consumption in Lithuania and EU-27 countries in 2005–2009 and 2011.

The comparison of final fuel and energy consumption of Lithuanian residential sector with EU-27 countries shows that the hugest final energy consumers were Germany (52,934–65,777 thousand toe), United Kingdom (35,839–44,645 thousand toe), France (36,948–43,848 thousand toe) and Italy (27,349–31,667 thousand toe). Lithuanian residential sector energy consumption (1508–1592 thousand toe), was comparable with Latvia (1318–1574 thousand toe), Croatia (1722–1926 thousand toe), Slovakia (2081–2540 thousand toe) and Bulgaria (2068–2380 thousand toe).

The share of residential energy consumption in the total final energy consumption in Lithuania and EU-27 countries in 2005–2009 and 2011 is shown in Fig. 12.

That share for Lithuania, Latvia, Estonia, Hungary, Romania and Poland was about 30–37% of the final country consumption, for Denmark, Germany, France, Croatia, United Kingdom, and Switzerland – 25–31%, for Belgium, Bulgaria, Czech Republic, Ireland, Italy, Austria and Slovenia – 20–26%. The average share of EU-27 countries was about 25%. The least share had Luxembourg – 10–13%.

4.2. Final fuel and energy consumption in households according energy sources

Distribution of fuel and energy in Lithuanian households according energy sources for the period 2005–2012 is shown in Fig. 13.

From 2005 to 2009 the final fuel and energy consumption in Lithuanian households sector fluctuated in the range 57–60 PJ. In 2010 it increased by about 13% to 65.5 PJ and in 2010–2012 changed marginally (64.3–66.7 PJ).

In 2005–2012, the heat and solid biofuels (wood, wood and agricultural waste) in Lithuanian households sector were consumed mostly, respectively 32–38% (20–23 PJ) and 29–37% (17–24 PJ). Natural gas consumption in households comprised about 9–11% (5.6–6.6 PJ), electricity – about 13–17% (7.7–9.8 PJ) and oil products – only 2.5–4.6% (1.6–2.7 PJ).

Final fuel and energy consumption distribution in Lithuanian households in 2012 is shown in Fig. 14.

The biggest share of fuel and energy in Lithuanian households belonged to solid biofuels (wood, firewood and agricultural waste) – 36.5% and heat energy – 31.7%.

Electrical energy in final fuel and energy consumption in households comprised 14.8%, natural gas – 8.8% and oil products – 3.8% (liquefied petroleum gas 3% and fuel oil 0.8%). For coal, peat and other fuel about 4.4% belonged to all households' final fuel and energy consumption.

The tendencies of fuel and energy consumption changes in Lithuanian households are shown in Fig. 15.

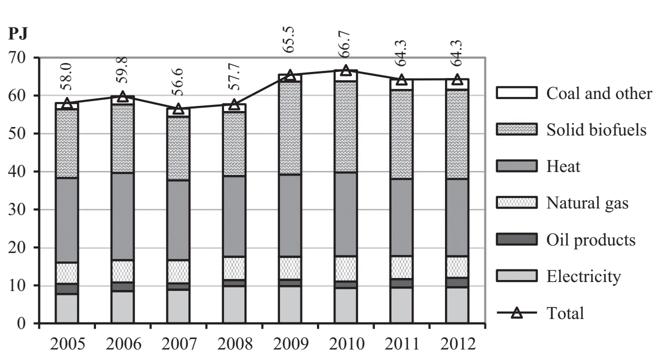

Fig. 13. Distribution of fuel and energy in Lithuanian households according to energy sources.

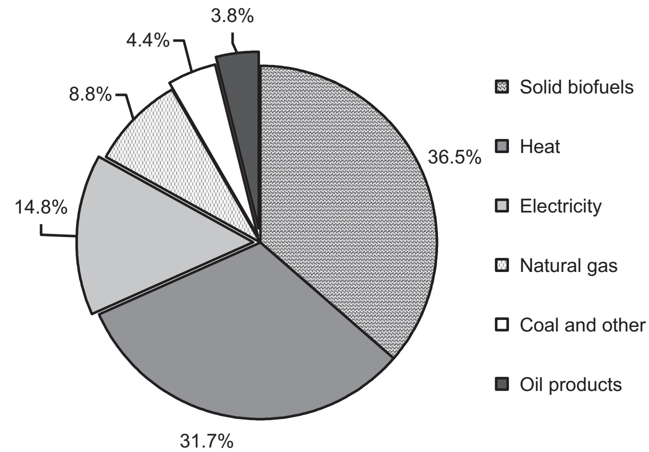

Fig. 14. Final fuel and energy consumption distribution in Lithuanian households in 2012.

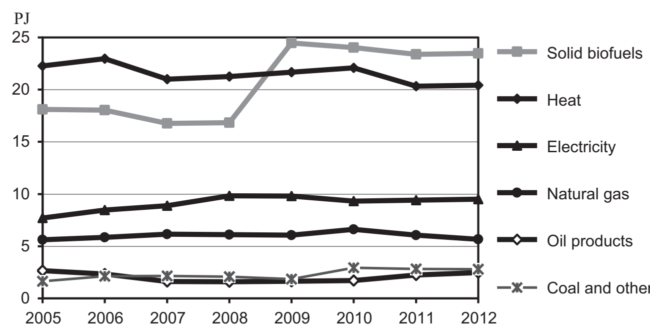

Fig. 15. Changes of fuel and energy consumption in Lithuanian households in 2005–2012.

Table 2
Average amount of fuel and energy consumed per household by the type of dwellings, kWh.

	All types of households	Single and two-family dwellings	Multi-family dwellings
Total	**13,590.2**	**18,364.2**	**10,652.5**
Heat	4497.8	129.6	7184.3
Electricity	1965.5	2477.3	1650.7
Solid biofuel	5135.4	12,150.1	821.2
Other fuel	1991.5	3607.2	996.3

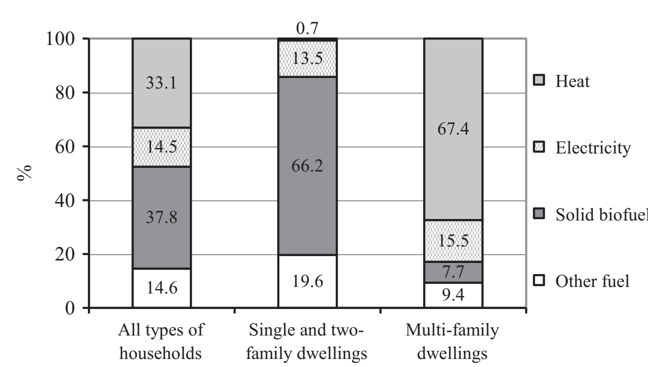

Fig. 16. Percentage average of fuel and energy consumed per household by type of dwellings.

In 2005–2012, the heat consumption in Lithuanian households slightly decreased from 23 to 20.4 PJ. The solid biofuels consumption in 2005–2008 decreased from 18.1 to 16.8 PJ, however in 2009 sharply increased to 24.5 PJ and in 2010–2012 – marginally decreased to 23.5 PJ. In 2005–2012, electricity consumption in Lithuanian households increased from 7.7 to 9.5 PJ (on about 23.4%).

Average amount of fuel and energy consumed per household by the type of dwellings in Lithuania is shown in Table 2 [85]. Average amount of energy consumed per household (by average heated area 63 m^2) was about 13,590 kWh.

According to the Statistics Lithuania, average amount of energy consumed in single and two-family dwelling (by average heated area 81 m^2) was about 18,364 kWh and in multi-family dwelling (by average heated area 51 m^2) – 10,652 kWh, i.e. by about 40% less. This difference arises from the fact that there are several exterior walls, a separate roof and more space in private houses; therefore, they need more energy.

Percentage average of fuel and energy consumed by dwelling type is shown in Fig. 16.

In single and two-family Lithuanian dwelling solid biofuels about 66.2% (firewood and wood waste) were consumed of all fuel and energy consumption. On the contrary, in multi-family Lithuanian dwelling was consumed mostly of heat – 67.4% of all fuel and energy consumption, and solid biofuels consumption consisted only 7.7%.

The average of energy consumed for heating a dwelling amounted on about 9650 kWh or 71% of total household energy consumption. The heating season in Lithuania lasts about 6 months and the heating of an area of 1 m^2 of a dwelling during the heating season required around 153 kWh of energy. This average energy consumption is relatively large and is partly determined by the fact that most residents of Lithuania live in old dwellings. The survey showed that 92% of dwellings in Lithuania were built before 1990 (about 70% – before 1980), while just about 8% – after the restoration of the independence of Lithuania.

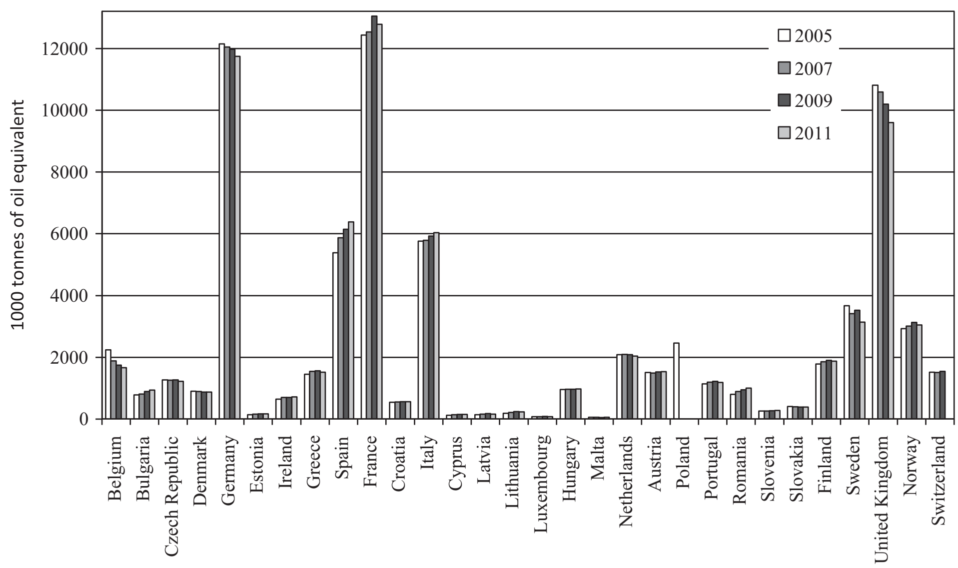

Fig. 17. Electricity consumption of households in Lithuania and EU-27 countries in 2005–2009 and 2011.

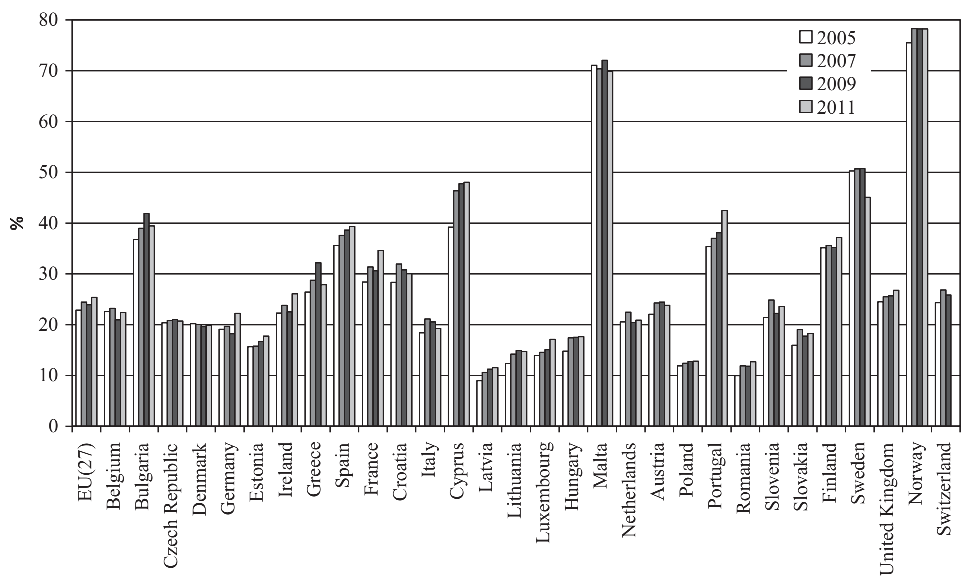

Fig. 18. Share of household's electricity usage in final energy consumption of residential sector for Lithuania and EU-27 countries in 2005–2009 and 2011.

4.3. Electricity consumption in Lithuanian and European households

The comparison of Electricity consumption of households in Lithuania and EU-27 countries in 2005–2009 and 2011 is shown in Fig. 17 [91].

Household's electricity consumption covers electricity for space and water heating and all electrical appliances. Electricity consumption in Lithuanian households sector was about 186–234 thousand tonnes of oil equivalent (toe) and was many times less the Germanys' (11,745–12150 thousand toe), Frances' (12,429–13047 thousand toe) or United Kingdoms' (11,745–12150 thousand toe) households consumption (9595–10809 thousand toe).

Lithuanian household's sector electricity consumption was comparable with Slovenia (254–276 thousand toe), Estonia (139–166 thousand toe) and Latvia (135–172 thousand toe).

Share of household's electricity usage in final energy consumption of residential sector in Lithuania and EU-27 countries in 2005–2009 and 2011 is shown in Fig. 18.

The highest share of household's electricity consumption in final energy consumption of residential sector had Norway and Malta (70–78%), also Sweden, Cyprus and Bulgaria (40–50%). Lithuanian, Estonian, Luxembourg, Hungarian, Poland, Romanian and Latvian shares were in the range of 10–18%.

The average of household's electricity consumption of EU-27 countries in 2005, 2007, 2009 and 2011 years comprised about 23%.

4.4. Electricity prices for household consumers

Electricity prices for household consumers in Lithuania and EU-27 countries for 2005, 2009, 2011 and 2013 are shown in Fig. 19 [92]. For the period 2005–2013 electricity prices for household consumers in Lithuania and all EU-27 countries increased remarkably. In Lithuania prices increased 1.86 times from 6.1 to 11.32 Eurocent per kWh, Latvia and Croatia – 1.6 times from 7 to 11 Eurocent per kWh, Poland and Finland – 1.4 times from 8 to 11.5 Eurocent per kWh. Mostly prices increased in Cyprus (from 9.2 to 22.8 Eurocent per kWh), Ireland (from 12 to 19.5 Eurocent per kWh), Spain (from 9 to 17.5 Eurocent per kWh) and Malta (from 7.3 to 16.2 Eurocent per kWh).

On average, electricity prices for household consumers of EU-27 countries increased by 1.4 times (from 10.1 to 13.8 Eurocent per kWh).

5. RES flows diagram in Lithuania and RES share for households

Renewable energy sources (RES) flows diagram and RES share to households sector in Lithuania in 2012 is shown in Fig. 20. The diagram was constructed by specialists of Lithuanian Energy Institute [93]. In 2012, supply of the RES in Lithuania consisted of 1164.8 thousands toe. Biggest share of such RES 85.7% (998.3 thousands toe) belonged to firewood and wood waste. Final energy from RES comprised 1101.3 thousands toe.

For households and services sectors about 81% (892.6 thousands toe) belonged to RES from which about 92% belonged to firewood and wood waste.

About 94% of final firewood and wood waste consumption belonged to households sector. So, as shown in the figure, households sector in Lithuania was the main RES consumer.

6. The reduction of GHG emissions in Lithuania and EU-27 countries

Up until the end of 2009, Lithuania had a good record of greenhouse gasses (GHG) emissions compared with other EU countries. However, at present Lithuania is facing a major rise in GHG emissions due to the closure of Ignalina NPP and the resulting increase in use of older thermal power plants.

In 2011 GHG emissions in Lithuania comprised 21.78 million tonnes of CO_2 equivalent and was 55.7% lower the base year 1990 emissions 48.75 million tonnes of CO_2 equivalent (well below the Kyoto target of -8%) [94].

The largest reduction of CO_2 emissions for the period 1990–2011 was in Germany (from 1250.26 to 940.29 million tonnes of CO_2 equivalent) and seek 310 million tonnes of CO_2 equivalent or 24.8%; also, in United Kingdom (from 767.33 to 585.86 million tonnes of CO_2 equivalent) on 181.47 million tonnes of CO_2 equivalent or 23.6%.

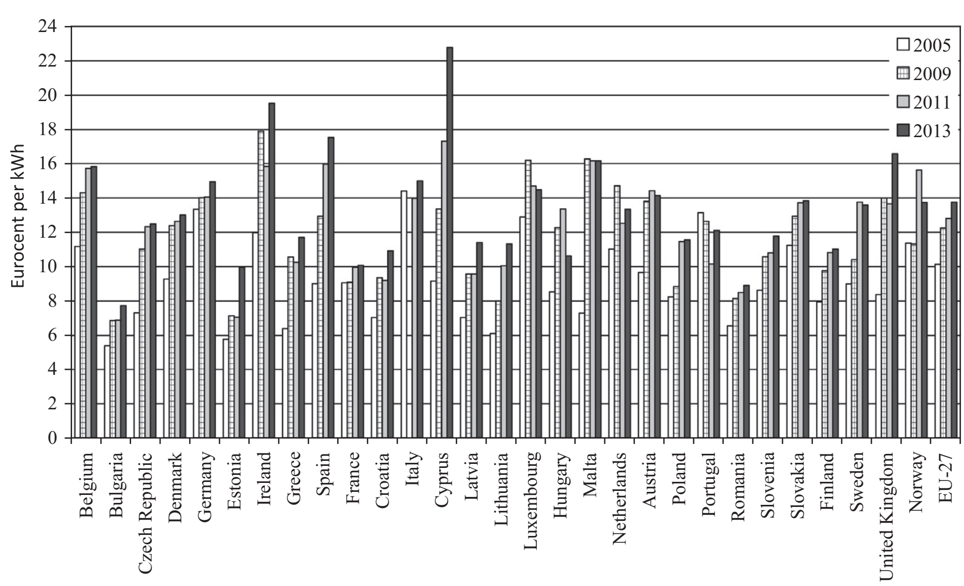

Fig. 19. Electricity prices for household consumers in Lithuania and EU-27 countries for 2005, 2009, 2011 and 2013.

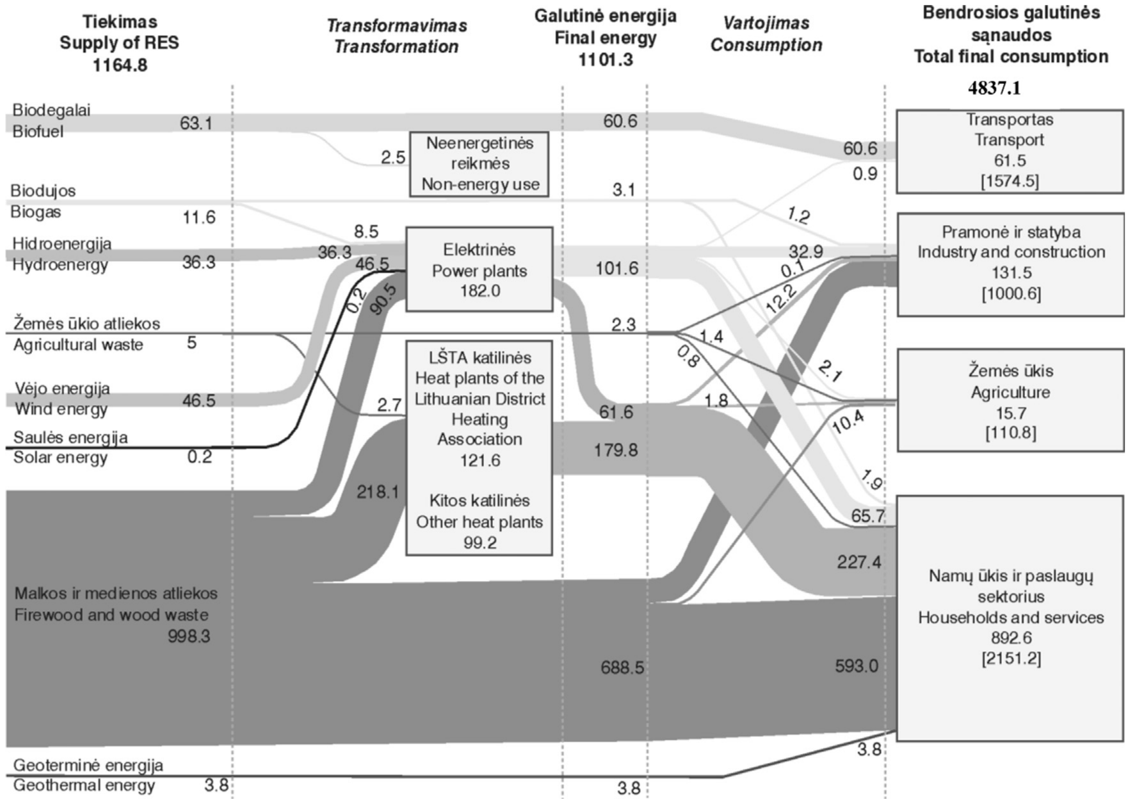

Fig. 20. RES flows diagram in Lithuania in 2012 and share for households, thousands toe [93].

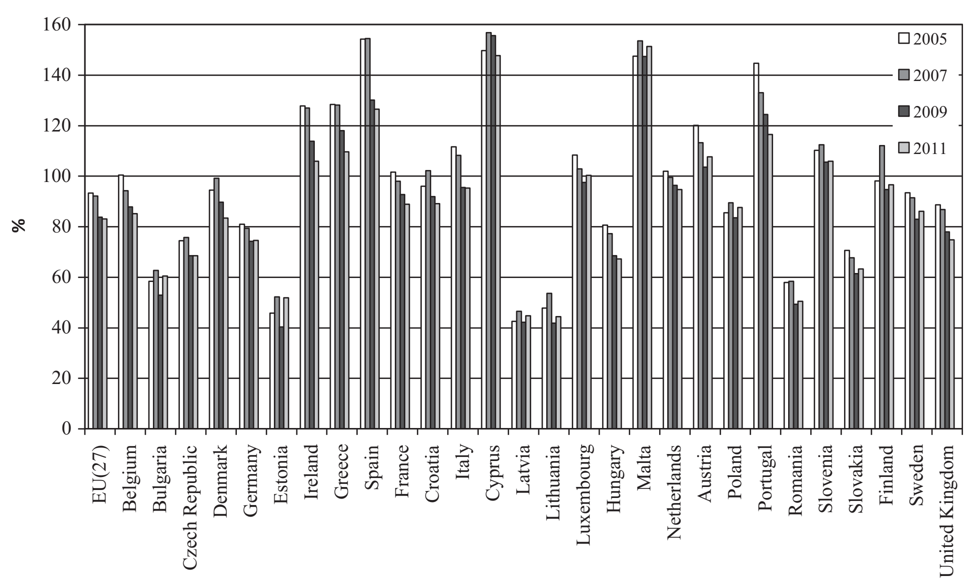

Fig. 21. Reductions of GHG emissions in Lithuania and EU-27 countries from the base year 1900 to 2005–2009 and 2011.

The Lithuanian GHG emissions are well below Germany's, United Kingdom's, France's or Italy's emissions and are comparable with Estonia's, Luxembourg's, Latvia's and Slovenia's emissions. The reductions of total GHG emissions in Lithuania and other EU-27 countries from the base year 1990 to 2007–2009 and 2011 are shown in Fig. 21 [95].

The total GHG emissions of EU-27 countries for the period 1990–2011 reduced about 16% (from 5574.42 to 4686.57 million tonnes of CO_2 equivalent). Till 2011, Lithuania, Latvia, Romania, Estonia and Bulgaria reduced the base year GHG emissions by 40–56%.

However, countries such as Portugal, Spain, Cyprus and Malta exceeded the base year GHG emissions respectively on 16%, 26%, 46%, and 50%. Austria, Slovenia, Greek and Ireland exceeded the base year GHG emissions on about 6–10%.

7. Conclusions

The Directive 2009/28/EC of the European Parliament of the Council on promotion of the use of energy from renewable sources

(RES) sets the overall target to reach 20% renewable energy in gross final energy consumption by 2020 [96]. This target is related with separate EU countries targets and Lithuanian target is to reach 23% of RES in gross final energy consumption till 2020. Reaching the set targets require a huge mobilization of investments in renewable energies not only for Lithuania but also for all EU countries.

Directive 2002/91/EC on the Energy Performance of Buildings (EPBD) was fully transposed into Lithuanian legal acts in 2006. All laws and administrative provisions necessary to comply with this Directive came into force in January 2006. The implementation of EPBD in Lithuania started in 2007. At first, the implementation of the Directive was the overall responsibility of the Ministry of the Environment and Ministry of Economy and at present – the Ministry of Environment and Ministry of Energy.

The reduction of energy consumption and usage the RES in households sector is one of the underlying strategic directions of EU. For implementation of set targets, in 2010 the new EU Directive 2010/31/EU (EPBD) was confirmed for increasing the buildings' energy efficiency and now Lithuania is on the way of implementing the recast EPBD.

In Lithuania the Energy Performance (EP) requirements are obligatory for new buildings and for existing buildings after major renovation, reconstruction or building repair works, when the total cost of the renovation relating to the building envelope or the technical building systems is higher than 25% of the building's value.

According to the new Directive, EK actuate that all new constructed buildings from the December of 2020 should be near the passive or zeroes energy consumption. By implementing such directive, the heat energy consumption in new constructed buildings should be extremely small and should approach to about 15 kWh/m^2 energy consumption per year.

Final fuel and energy consumption in Lithuanian households sector was 57–67 PJ for the period 2005–2012. The heat energy in Lithuanian households consisted about 32–38% and solid biofuels – about 30–36%. As were stated in National Energy Independence Strategy of the Republic Lithuania [82], Lithuania has a developed district heating system with around 65% of consumed heat produced in centralized systems. The share of district heating in the whole heating sector remained fairly constant over the last years. The major problem in the heating system is inefficiency at the point of consumption – the average yearly heat consumption of Lithuanian buildings is 209 kWh/m^2, which is substantially higher than the average of Nordic countries (128 kWh/m^2). Reducing this inefficiency can bring substantial savings of heating costs and would lower emissions of greenhouse gas.

At present the heat supplied in district heating systems is produced mainly from the fossil fuels – approximately 70% is produced from gas, which is imported from a single source. Increasing energy production from renewable energy can diversify energy sources for heat production and reduce negative impact of the district heating sector on the environment.

One of the main Lithuanian tasks is the increasing efficiency of heat consumption. By increasing energy efficiency of households and public buildings, 2–3 TWh heat savings should be achieved in 2020. Compared to 2011, these savings would amount to 30–40% of final heat consumption. Lithuania will strive to realize most of the identified savings potential, as reducing heat consumption is very beneficial. It brings increased energy independence and positive impact on the local economy for the state, reduced heating bills – for energy consumers, and reduced pollutant and GHG emissions – for the environment. Therefore, Lithuania should implement all economically justified heat energy consumption efficiency initiatives.

Second main task is heat savings in production and distribution. Apart from savings in heating consumption, further savings will be sought in production and transportation of heat by gradually improving the heat production and transportation infrastructure. In heat transmission, as much as 0.4 TWh is expected to be saved annually by gradual replacement of outdated and insecure heat transmission grid. In heat production, savings will be achieved by replacing old less efficient boilers with newer more efficient boilers using biomass and by installing combined heat and power (CHP) biomass plants.

The next task is heat consumption savings. In Lithuania by 2020 the heat consumption will be reduced by 30–40% in buildings, the majority of which will have been insulated. In order to achieve this, sufficient financing has to be secured. Also, since the investment level is substantial, there is a need to prioritize insulation projects – houses in which the highest potential of heat consumption increase is expected will be renovated first:

(1) the initiative will increase energy independence of Lithuania – consumption of gas for district heating will decrease. This will lead to annual savings of over 400 million LTL (Lithuanian Litas) that would otherwise be spent on natural gas import. For households, investment into the efficiency of heat energy consumption will bring annual savings of approximately 600 million LTL on heating costs – or over 500 LTL per household;
(2) renovation will also increase economic and social value of the renovated real estate, especially in the least energy efficient houses;
(3) initiatives for heat efficiency will make the heating sector more environmentally friendly by decreasing CO_2 emissions. As a result of efficiency gains, emission of 1.1 million tonnes of CO_2 equivalent in the heating sector will be prevented, which represents more than 5% of total GHG emissions of Lithuania in 2008.

In order to achieve a substantial large energy efficiency improvement, 5–8 billion LTL will have to be invested in the renovation of buildings. Renovation will be financed by the State, EU structural funds, and home owners. The estimated payback period is 10 years.

Increasing the share of renewable energy sources in the heating sector in Lithuania should be achieved by enhancing the use of biomass. The State will encourage economically viable investment into heat production from biomass with priority on biomass CHPs which will produce additional 2.3 TWh of heat. Another 1.1 TWh of heat will be produced each year in new biomass boilers. Investment into this production will not increase heat prices and will enable to achieve that the share of RES in the final energy consumption balance in 2020 would make up not less than 23%. Concrete decisions on capacities of biomass boilers or biomass CHPs should be adopted taking into account the particularity of heat consumption in separate central heating systems.

In 2011 the share of RES in the final energy consumption amounted to around 20%. The major portion of it is covered by biomass, which will continue to play a leading role in the energy production from RES. The given Lithuania's natural conditions, the potential of wind and biomass energy is not fully exploited yet. Therefore, necessary technical, economic conditions and regulatory framework should be created for the better usage of wind and biomass economically viable potential.

The energy consumption per unit of GDP in Lithuania is 2.5 times higher than EU average and can be reduced significantly if the overall energy savings will be increased.

The total savings potential of final energy consumption in Lithuania by 2020 is approximately 17% compared to the final energy consumption in 2009 (not including the increase in energy

consumption caused by the growth of GDP). Realization of this potential would imply yearly savings of 740 kt of oil equivalent (ktoe) by 2020.

The largest energy saving potential exists in the household and transport sectors, where energy efficiency measures constitute 65% of total energy savings. The potential for households sector amounts to 290 ktoe and for the transport – 300 ktoe. Furthermore, households and services sectors electricity efficiency saving potential amounts 70 ktoe by major levers on energy efficient public procurement and appliances labeling. Heat efficiency saving potential of households and services sectors amounts to 220 ktoe (mainly by insulation of buildings and modernization of multi-apartment houses). Buildings insulation and transport improvements are the biggest energy efficiency levers.

Taking into account the total amount of energy that can be saved the overarching strategic goal in energy efficiency is to achieve 1.5% annual savings of the total final energy consumption by 2020.

In residential and public buildings energy efficiency will be increased by insulation and modernization of buildings. It will bring 220 ktoe energy annual savings from efficient heating and 70 ktoe savings will be reached by public procurement promoting efficiency and greater use of more efficient appliances.

Energy efficiency of the transport sector will be improved by measures to promote the renewal of car fleet in the country, a shift towards modern and environmentally friendly public transport, optimizing transport infrastructure and promoting investments into environmentally friendly means of transport.

Based on a study by the Energy Economics Group that was adopted in the Lithuanian National Energy Efficiency Program 2011–15, the total calculated energy savings potential in Lithuania until 2020 is about 17%.

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